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That I am knowledgeable in the English language and in the language in which the below-identified international application was filed, and that I believe the English translation of the German application No. 102 60 703.6 is a true and complete translation of the above-identified German application as filed.

I further declare that all statements made herein on my own knowledge are true and that all statements made on the information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the *United States Code* and that such willful false statements may jeopardize the validity of the application or any registration resulting therefrom.

Date: June 8, 2006

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COMBUSTION-ENGINED SETTING TOOL

The present invention relates to a combustion-engined setting tool for driving fastening elements described in the preamble of claim 1.

Combustion-engined setting tools of the type described above can operate with gaseous or liquid fuels that are combusted in the combustion chamber, and thereby drive a drive piston for fastening elements.

Generally, the problem with the fuel consists in admixing, for each operational cycle, a corresponding amount of air or oxygen used as an oxidation medium. The amount of oxygen, which is available for use in combustion, depends strongly on the surrounding temperature, air pressure, and air humidity. The necessary amount of fuel varies greatly with changes in the above-listed parameters, up to 40% in an extreme case. These variations of the amount of fuel unfavorably influence the combustion of the air-fuel mixture when the fuel-air mixture contains too much or too little fuel. Therefore, it is desirable to adapt the used amount of fuel to the respective environmental conditions. In order to achieve an optimal combustion, it is further desirable to inject the fuel into the combustion chamber with as high a speed as possible.

EP-1 254 745 A2 discloses a setting tool of the type discussed above and having a metering valve in which the volume of the metering chamber is adjusted with a spindle projecting into the metering chamber. For changing and preliminary setting of the inner volume of the metering chamber, the spindle is displaced into the metering chamber to a greater or lesser degree. The displacement is effected manually by screwing the spindle in or out of the metering chamber. The feeding of fuel to the combustion chamber is effected through an outlet valve under the own pressure of the fuel filling the metering chamber.

EP-0 597 241 B1 disclosed a combustion-engined setting tool in which feeding fuel from a fuel source to a combustion chamber is effected with metering device that includes a normally closed solenoid valve. The actuation is effected electronically and is controlled by a switching circuit which responds to a switch and opens the valve in a predetermined time interval to enable flow of fuel from the fuel source to the combustion chamber.

The drawback here consists in that with variations of the initial pressure in the fuel source, the flow velocity of the fuel varies and can result in feeding

of a non-exact amount. The flow of fuel into the combustion chamber takes place under the fuel own pressure in this setting tool.

DE-42 43 617 A1 discloses a setting tool in which in an operational cycle, a gas inlet valve opens mechanically, and fuel from a fuel source is fed into a storage chamber which communicates with the surrounding air. This communication provides for a pressure and, if necessary, temperature equalization with the surrounding air, so that a proper air-fuel mixture is fed into the combustion chamber at a predetermined time.

The drawback here consists in that the communication with the surrounding air can result in loss of fuel. Further, the pressure in the metering chamber cannot be controlled.

The object of the present invention is to provide a setting tool of the type described above in which the above-discussed drawbacks are eliminated, an exact metering of fuel is insured, and a high setting energy is achieved. This is achieved, according to the invention, by means recited in claim 1, of which the following is of utmost importance.

According thereto, the metering device has a displaceable body for pressing out of a metered volume of fuel from the metering chamber.

Therefore, the inner volume of the metering chamber is reduced to zero in pulse-like manner. With the displaceable body movable in a pulse-like manner, the amount of fuel metered out in the metering chamber of the metering device, is ejected from metering chamber with a high speed. With this solution, a direct injection system that meters the fuel under a high pressure through one or several fine nozzles into the combustion space or combustion chamber is provided. This results in an advantage that consists in that the ejected, through the pumping valve, spray with a high turbulence and very fine drops permits to obtain a high evaporation rate even of fuel with a low-boiling point, which enables a favorable cold temperature behavior of the setting tool.

According to an advantageous embodiment of the present invention, the output volume of the metering chamber is pre-adjusted by adjusting the initial position of the displaceable piston body.

According to another advantageous embodiment of the present invention, the metered volume of the metering chamber is adjusted with an adjustment

device. The metering chamber volume in the initial position of the metering device is determined by an axial distance between a static body and a bottom of the oppositely located displaceable piston body. The adjustment device adjusts or changes the axial distance between the static body and the displaceable body in the initial position of the metering device. In this way, the displaceable body, the "ejection body" performs a double function, which simplifies the structure of the metering device.

According to one of preferred embodiments of the inventive setting tool, there can be provided, in the setting tool, sensor means, *e.g.*, for sensing the surrounding temperature. The sensor means can cooperate with the adjustment device of the metering device, so that the adjustment device adjusts the metering chamber volume, *e.g.*, dependent on the temperature sensed by the sensor means, by adjusting the position of the displaced body relative to the static body. This measure permits to feed into the combustion chamber an optimal fuel-air mixture corresponding to the temperature of the surrounding air.

According to another advantageous embodiment of the setting tool, the adjustment device can be operated manually, with use of an adjusting screw. The manual operation is effected by the user who adjust the position of the adjusting screw, *e.g.*, according to a cold or warm operation.

According to yet another advantageous embodiment of the setting tool, there can be provided sensor means that senses in addition to the surrounding temperature, other environmental parameters, e.g., parameters of the power tool such as, *e.g.*, the temperature of the combustion chamber. The obtained measurement data or parameters are transmitted by the sensor means to a control device which, in turn, transmits appropriate commands to the adjustment device for the metering device. The control device can also control the metering device dependent on the obtained data for obtaining an optimal air-fuel mixture.

According to a further advantageous embodiment, the displaceable body has opposite actuation or piston surfaces which are located in the piston space and are subjected to hydraulic pressure and/or pneumatic pressure. By applying the hydraulic or pneumatic pressure, the displaceable piston body can be

displaced in a pulsed manner, ejecting the fuel from the metering chamber with high speed. For obtaining the hydraulic and/or pneumatic pressure, there can be provided hydraulic and/or pneumatic means which communicates with respective piston chambers and provide for application of pressure to the respective actuation surfaces. The hydraulic or pneumatic means can be controlled by the control device and/or a separate switch means.

The metering chamber can have an inlet, an outlet, and valve means provided at the inlet and the outlet and allowing flow of fuel only in a direction to the combustion chamber. An error-free operation of the metering device is thereby insured.

According to a further advantageous embodiment of the present invention, the displaceable body is formed as a pot-shaped piston a pot space of which forms the metering chamber. The pot space serves for sealingly receiving the static body that functions as a displacement body with which the fuel volume, which fills the pot space or the metering chamber, can be ejected. To this end, advantageously, an axial through-channel is formed in the static body which forms an outlet of the metering device. Advantageously, the outlet

has a nozzle opening, or a nozzle is provided thereat through which the fuel, which is ejected through the through-channel, is injected into the combustion, *e.g.* in form of a fine mist. This construction insures compactness of the metering valve.

It is further advantageous when the opening of the through-channel adjacent to the metering chamber forms a valve seat sealingly engageable by a valve head of a valve body, e.g., a valve rod. The valve body or the valve rod is displaceable axially through a passage formed in the displaceable body and its pot space. In the initial position of the metering device, the valve seat, together with the valve head, insure an absolute fluid tightness so that no fuel can penetrate into the combustion chamber before actuation of the metering or pumping valve.

Further advantages and features of the invention follow from subclaims, following description, and the drawings. In the drawings, three embodiments of the invention are shown.

The drawings show:

Fig. 1 a longitudinal partially cross-sectional view of a setting tool according to the present invention;

Fig. 2 a longitudinal cross-sectional view of the metering device of the setting tool of Fig 1 with a metering chamber in a first initial position and with an electronically actuated adjustment device for adjusting the metering chamber volume;

Fig. 3 a longitudinal cross-sectional view of the metering device according to Fig. 2 with a metering chamber in a second initial position and with a hydraulic adjustment device for the metering chamber volume;

Fig. 4 a longitudinal cross-sectional view of the metering device according to Fig. 2 with a metering chamber in a third initial position and with a manually actuated adjustment device for the metering chamber volume;

Fig. 5 A longitudinal cross-sectional view of the metering device of Fig. 4 in an intermediate position; and

Fig. 6 a longitudinal cross-sectional view of the metering device of Fig. 4 in its end position.

Fig. 1 shows a first embodiment of setting tool 10 according to the present invention in its initial or inoperative position. The setting tool 10 is driven by a fuel gas. The setting tool 10 has a housing 14 in which a setting mechanism is arranged and with which a fastening element (not shown) can be driven in a constructional component (likewise not shown) when the setting tool 10 is pressed against the constructional component and is actuated. The setting tool 10 includes a combustion space or a combustion chamber 13, a piston guide 17, in which a drive piston 16 is displaceably arranged, and a bolt guide 18 in which a fastening element can be driven, wherein the fastening element is driven in a constructional component by the front, in a setting direction, end of the drive piston 16 when the drive piston 16 is displaced in a setting direction. The fastening elements can be stored, *e.g.*, in a magazine 19 attachable to the setting tool 10.

In the foregoing embodiment, an ignition device, *e.g.*, a spark plug 23 is arranged in a combustion chamber 13 for igniting a fuel gas-air mixture which is fed into the combustion chamber 13. The fuel gas is fed into the combustion chamber 13 from a fuel reservoir of fuel source 11 through a fuel conduit 12. The feeding direction of the fuel gas from the fuel reservoir 11 to the combustion chamber 13 is shown in Fig. 1 with arrow 26.

A metering device 30 is arranged in the fuel conduit 12 and which is shown in Fig. 2 in more detail.

The inventive setting tool 10 further includes, according to Fig. 1, an electronic control device 20 which is connected with a current source 27 such as, *e.g.*, a battery or an accumulator, by an electrical conductor 47.

The control device 20 can, *e.g.*, include a microprocessor in which a control program for one or several tool functions can be run. The control device 20 can control the metering of fuel by controlling operation of an adjustment device 50 for the metering device 30. The fuel is fed from the metering device 30 into the combustion chamber 13 in form of a mist when the metering device 30 is actuated by an actuation device 70, *e.g.*, pneumatic valve

means. The actuation device 70 can itself be actuated by the control device 20 and/or a separate switch means 24 such as, *e.g.*, a bar-shaped end switch connected with the actuation device 70 by an electrical conductor 24.1 or a mechanical bar.

The control device 20 is connected with the adjustment device 50 by an electrical conductor 44. An electrical conductor (not shown) connects the control device 20 with the spark plug 13. Switch means or a trigger switch 25 is provided on a handle 15 of the setting tool 10 and is connected with the control device 20 by an electrical conductor 45. The trigger switch is actuated electronically. The control device 20 is adapted to process measurement data and parameters of different sensors, such as, *e.g.*, a sensor 21 for sensing the air pressure and the temperature of the surrounding air and a sensor 22 for sensing the temperature in the combustion chamber 13. Electrical conductors 41, 42 connect the sensors 21, 22 with a control device 20. The electrical conductors 41, 42, 44, 45, 47 can be used for both supplying the electrical power and for an electronic data transmission. Besides the sensors 21 and 22, other sensors can be provided for sensing and transmitting measurement data to control device

20. The other sensors can, *e.g.*, be used for determining parameters of the setting tool such as, *e.g.*, a position of the piston.

Fig. 2 shows a first embodiment of a metering device 30 according to the present invention. The metering device 30 has a housing part 60 including a receiving chamber 60.1 in which a body 34 formed as a pot-shaped piston is displaceably arranged. The piston body 34 is sealed against the housing part 60 with seals 59. Further, in the reduced diameter region of the receiving chamber 60.1, a static body 35 is located that is displaceable into a pot-shaped space 37 of the body 34 and is sealed at its edge against the pot-shaped space 37 with a seal 58, *e.g.*, an O-ring. In the initial position of the metering device 30 or the pumping valve shown in Fig. 2, the displaceable body 34 is located in its initial position 28.1 in which its end remote from the static body 35 abuts a further housing part 61 that closes the receiving chamber 60.1. In this initial position, a metering chamber 31 or a metering space is formed between a bottom 39 of the pot-shaped space 37 and the static body 35 and the volume of which is defined by an axial distance 38.1 between the bottom 39 and the edge region of the static body 35. In the initial position of the metering device 30, through an inlet 32, to which the fuel conduit 12 is connected (see Fig. 1), the fuel, *e.g.*, in a

liquid form, can be fed into the metering chamber 31. A valve 62, which is formed, in this embodiment, as a resilient annular member, provides for flow of fuel through the inlet 32 in the metering chamber 31 but prevents a return flow of fuel from the metering chamber 31 into the inlet 32. The static body 35 has an axial through-channel 64. This through-channel has, at its end adjacent to an outlet 33 which communicates with the combustion chamber 13, an injection opening 65 the cross-section of which is reduced in comparison with the through-channel 64. The injection opening 65 is designed for obtaining a fine fuel mist when the fuel is ejected under pressure from the metering chamber 31 upon initiation of a setting process. A valve 63 separates the metering chamber 31 from the outlet 33. The valve 63 is formed, in this embodiment, of a valve body 69, *e.g.*, a valve rod and a valve head 68 that sealingly engages a valve seat 67 provided in the static body 35. In the initial position of the metering device 30, which is shown in Fig. 2, the valve 63 occupies a closed position in which the valve head 68 is engaged in the valve seat 67, whereby the through-channel 64 and, thus, the outlet 33 is closed. The valve body 69 or the valve rod is axially displaceable in the pot-shaped space 37 and in a passage 40 in the displaceable body 34. A seal 59.1 seals the valve body 69 against the passage

40 or the through-bore in the displaceable body 34. The valve body 69 is supported at its end remote from the valve seat 67 by a spring 66 against a housing part 61.1 of the metering device 30. The spring 66 biases the valve body 69 and retains it in its sealing position against the valve seat 67.

For adjusting the interior volume of the metering chamber 31 in the initial position of the metering device 30, the metering device 30 is associated with the adjustment device 50. The adjustment device 50 has, in this embodiment, a motorized drive 54 which is controlled by the control device 20 through control conductors 44 (see Fig. 1). The drive 54 drives a gear 54.1 that is engaged with a gear 55.1 mounted on an adjustment member 55, whereby the adjustment member 55 rotates upon actuation of the drive 54. Screw actuator means 52, which is located in the housing part 61, provides for an axial displacement of the adjustment member 55 in response to the rotational movement induced by the drive 54, whereby the adjustment member 55 displaces the displaceable body 34, acting with its end region 56 on stop means 34.1 on the body 34. As a result, the displaceable body 34 can continuously be displaced to different initial positions.

For a pulsed operation the metering device 30, in the foregoing embodiment, an actuation device 70 is provided, which is formed as a pneumatic valve. The pneumatic valve is subjected to action of a pressure medium, e.g., compressed air from a source (without reference numeral). Different operational surfaces 36 and 36.1 of the displaceable body 34 can be subjected, respectively, to the action of the adjusting pressure that is communicated thereto via connection conduits 71 and 72. To this end, there are provided respective piston chambers 73 and 74 through which the pressure medium acts on the operational surfaces 36 and 36.1. In the position of the metering device 30 shown in Fig. 2, the piston chamber 73, which is associated with the operational surface 36, is reduced to a size of a slot, because in the initial position, the metering chamber 31 has a maximal axial extent. The connection conduit 71, which is connected with the piston chamber 73, is aerated and remains pressureless in the shown position of the metering device 30. The connection conduit 72, which communicates with the piston chamber 74 associated with the operational surface 36.1, remains under pressure or is pressurized, retaining the displaceable piston body 34 in its initial position 28.1.

The precise function of the actuation device 10 will be discussed in detail further below with reference to Figs. 4-6.

Fig. 3 shows another embodiment of a valve device according to the present invention which is used in a setting tool according to claim 1. This metering device 30 differs from the metering device shown in Fig. 2 in that it includes a different adjustment device 50. Instead of a motor drive, a hydraulic device for a preliminary adjustment of the initial position of the displaceable body 34 is provided. Here, an adjustment member 55 is provided with surface 55.2 arranged in a piston chamber 57 of a housing part 61.2 of the metering device 30. The piston chamber 57 is filled with pressure medium and is connected by an opening 49 with a reservoir 48 for a hydraulic medium. On the reservoir 48, sensor means 22.1 for sensing, *e.g.*, the temperature of the environmental air, are mounted. Dependent on the temperature of the surrounding air, a greater or lesser amount of the hydraulic medium is withdrawn from the reservoir 48 and is fed through the opening 49 into the piston chamber 57, so that the hydraulic medium in the piston chamber 57 acts on the end surface 55.2 of the adjustment member 55, displacing the adjustment member 55 against a biasing force of a spring 46. The adjustment member 55,

which is displaced through the housing part 61, presses with its opposite end region 56 a stop 34.1 which is provided on the displaceable body 34, for displacing the displaceable body 34. The displaceable body 34 is subjected, in its initial position 28.2, to action of the pressure medium which is communicated by the actuation device 70 through the conduit 72 into the piston chamber 74 and which acts on the end surface 36.1, retaining the displaceable body 34 in engagement with the end region 56 of the adjustment member 55. The housing part 61.2 is closed with a cover 61.3 against which a spring member 66 for the valve body 69 is supported. In the initial position 28.2 of the displaceable piston body 34, shown in Fig. 3, the axial distance 38.2 between the bottom 39 of the metering chamber 31 and the static body 35 is significantly reduced in comparison with the same distance in Fig. 2. Therefore, the inner volume of the metering chamber 31 in the initial position 28.2 is smaller. When the sensor means 22.1 senses very cold temperatures, the hydraulic medium would flow through the conduit 49 back into the reservoir 48, and the displaceable body would displace to its original initial position shown in Fig. 2, in which the metering chamber 31 assumes its maximum volume. It is to be noted that the displaceable piston body 34 can occupy a plurality of different

intermediate positions. For particularities and functions of elements of the metering device 30 shown in this embodiment, and identical to those of Fig. 2, reference should be made in its entirety to the description with reference to Figs. 1 and 2.

Fig. 4 shows a third embodiment of a metering device 30 for operation of the setting tool. The metering device 30 differs from the metering devices described above again by the construction of the adjustment device 50. The adjustment device 50 includes an adjusting screw 51 which is manually set by the user. The adjusting screw 51 can be axially displaced by rotation because the adjusting screw 51 cooperates with an inner thread 52 provided in the housing part 61, whereby the position of the displaceable piston body 34 in the receiving chamber 60.1 of the housing part 60 is adjusted. Thereby, the user adjusts the axial distance 38.3 between the bottom 39 and the metering chamber 31 and the static body 35. In a head region of the cylindrically shaped adjusting screw 51, there is provided a piston chamber 57 in which a valve piston 75 is arranged. As shown in Fig. 4, the displaceable piston body 34 is located in a third position 28.3 in which the metering chamber 31 has an intermediate volume. For other particularities and functions of the metering device 30

shown here, reference should be made in its entirety to the description made with reference to Figs. 1-3.

For actuating the metering device 30, the actuation device 70 or the pneumatic device is actuated, whereby the conduit 71 is pressurized, while the conduit 72 is depressurized. With pressurization of the conduit 71 and depressurization of the conduit 72, the displaceable piston body 34 is displaced in pulse manner in the direction shown with arrow 80. The intermediate position is shown in Fig. 5. The pot-shaped space 37 overruns the static body 35, whereby the fuel volume which fills the metering chamber 31, is almost completely ejected from the metering chamber. Before the start of the ejection process, the piston 75, which is located in the piston chamber 57 of the adjusting screw 51, is displaced, together with the valve rod 69, in a direction opposite the closing direction of the valve rod 69 and against the biasing force of the spring 66, whereby the valve rod 69 is lifted off the valve seat 67. Thereby, the outlet 33 becomes open, and the fuel mist 81 is ejected through the nozzle opening 65 and through the outlet 33. In Fig. 6, the displaceable piston body 34 of the metering device 30 is displaced in its end position 29. In this end position 29, the volume of the piston chamber 74 is zero, and the metered

volume of the fuel has almost completely been ejected from the metering chamber 31 through the nozzle opening 65 and delivered to the combustion chamber 13. For returning the displaceable body 34, the conduit 71 can be depressurized by the actuation device 70, and the conduit 72 is pressurized. A new injection cycle can be initiate again.

CLAIMS:

1. A combustion-engined setting tool for driving fastening elements such as nails, bolts, pins in a constructional component, comprising a fuel source (11); a fuel conduit (12) connecting the fuel source (11) with a combustion chamber (13); and at least one metering device (30) for metering fuel for setting processes, wherein the at least one metering device (30) has at least one metering chamber (31) with an adjustable metering chamber volume for metering of a predetermined amount of fuel,

characterized in that

the metering device (30) has a displaceable body (34) for a pulsed ejection of a fuel volume measured in the metering chamber (31).

2. A setting tool according to Claim 1,

characterized in that

the metered chamber volume is adjusted by adjusting an initial position (28.1, 28.2, 28.3) of the displaceable body (34).

3. A setting tool according to Claim 1 or 2,

characterized in that

the metering chamber (31) is enclosed between the displaceable body (34) and a static body (35), wherein the metering chamber volume is adjusted by an adjustment device (50) acting on the displaceable body (34).

4. A setting tool according to one of Claims 1 to 3,

characterized in that

there is provided sensor means (22.1) for sensing temperature of a surrounding air and cooperating with the adjustment device (50) for the metering chamber volume.

5. A setting tool according to one of Claims 1 through 3

characterized in that

the adjustment device (50) is manually operable and includes, optionally, an adjusting screw (51).

6. A setting tool according to one of Claims 1 through 4,

characterized in that

on the setting tool, there is provided a sensor means for sensing parameters of the setting tool and/or environmental parameters and for communicating the sensed parameters to a control device (20) for the metering device, wherein a volume of the metering chamber (31) for each operational cycle is adjusted dependent from parameters by the control device (20).

7. A setting tool according to one of Claims 1 through 6,

characterized in that

the displaceable body (34) has adjusting surfaces (36, 36.1) which are subjected to hydraulic pressure and/or pneumatic pressure, whereby it is displaced in a pulsed manner.

8. A setting tool according to one of Claims 1 through 7,

characterized in that

there is provided hydraulic valve means, optionally pneumatic valve means for subjecting the adjusting surfaces (36, 36.1) to the hydraulic and/or pneumatic pressure, and which is controlled by the control device (20) and/or a switch (24).

9. A setting tool according to one of Claims 1 through 8,

characterized in that

the metering chamber (31) has an inlet (32) and an outlet (33), and valve means (62, 63) provided at the inlet (32) and the outlet (33) and which allows flow of fuel only in a direction to the combustion chamber (13).

10. A setting tool according to one of Claims 1 through 9,

characterized in that

the displaceable body (34) is formed as a pot-shaped piston a pot space (37) of which forms the metering chamber (31) and is formed for sealingly receiving the static body (35).

11. A setting tool according to one of Claims 1 through 10,

characterized in that

the inlet (33) is formed by an axial through-channel (64) in the static body (35) and which has, at an end thereof remote from the metering chamber (31), a nozzle opening (65).

12. A setting tool according to one of Claims 1 through 11,

characterized in that

in the region of an opening of the axial through-channel (64), a valve seat (67) for sealingly receiving a valve head (68) of a valve rod (69) is provided, wherein the valve rod (69) is displaced through a passage (40) in the displaceable body (34) and the pot space (37) thereof.

ABSTRACT:

The foregoing amendment relates to a combustion-engined setting tool for driving fastening elements such as nails, bolts, pins in a constructional component, comprising a fuel source (11); a fuel conduit (12) connecting the fuel source (11) with a combustion chamber (13); and at least one metering device (30) for metering fuel for setting processes, wherein the at least one metering device (30) has at least one metering chamber (31) with an adjustable metering chamber volume for metering fuel portions of an adjustable amount. For the improvement of such setting tools, the metering device (30) has a displaceable body (34) for a pulsed reduction of the inner volume of the metering chamber (31).